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Neonatal screening of hearing function by otoacustic emissions – a single center experience

Neonatalno ispitivanje slušne funkcije metodom otoakustičkih emisija – iskustvo jednog centra

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Abstract

Background/Aim. Nowadays development of techniques enables detection of hearing impairment in a very short time, immediately after birth by using otoacoustic emissions. They are low-pitched sounds produced in physiologically clear cochlea and can be recorded in cochlear outer meatus. By this method, complete data are found on a whole presynaptic auditory nervous system functioning that has mostly been affected by pathological changes making it a perfect screening test. Reliability and sensibility of this method is up to 98%. The aim of this study was to present the first results of systematic neonatal screening of hearing function by otoacoustic emissions in the Clinical Center Kragujevac (Kragujevac, Serbia). **Methods.** This prospective study of neonatal hearing screening function, initiated systematically by the 2008 at the Clinical Center Kragujevac, included full-term newborns and premature born ones, within the first 24 h after birth, using a DPOAEs interacoustics otoread-screener. Retesting was done after a month. **Results.** From January 1st, 2009 to December 1st, 2010, a total number of examined infants by this method was 1,994 out of which 1,778 were full-term and 216 were premature born. The test passing was higher in the group of full-term babies (92.5%) than in the preterm ones (55.1%). No bilateral answers were recorded in premature born children compared to the full-term ones, of whom a larger number was with missing lateral responses. The results of re-examination test in the group of full-term born and premature newborns were 83.7%, and 61%, respectively. **Conclusion**. Deliberately provoked transient otoacoustic emission is an efficient method in testing hearing function in newborns, since it is non-invasive, rapid and objective. Its correlation with audibly evoked potentials is very high, which confirms its reliability.

Key words:
infant, newborn; infant, premature; hearing; hearing tests; evoked potentials, auditory.

Apstrakt

Uvod/Cilj. Razvoj tehnike danas omogućio je da se metodom otoakustičkih emisija za vrlo kratko vreme dobije uvid u stanje sluha kod deteta neposredno posle rođenja. Cilj rada bio je da se prikažu prvi rezultati sistematskog neonatalnog ispitivanja sluha metodom otoakustičkih emisija u Kliničkom centru Kragujevac (Kragujevac, Srbija). **Metode.** Ova prospektivna studija ispitivanja neonatalne slušne funkcije, započeta sistematski krajem 2008. godine u Kliničkom centru Kragujevac, obuhvatila je decu rođenu na vreme i prevremeno rođenu decu i to 24 h posle rođenja. Testiranje je vršeno pomoću aparata DPOAEs Interacoustics OtoRead-Screener, kao i retestiranje nakon mesec dana kasnije. **Rezultati.** Od 01. 01. 2009. do 01. 12. 2010. ovom metodom ispitano 1 994 novorođenčadi, od čega 1 778 rođenih na vreme i 216 prevremeno rođenih. Prolaznost na testu bila je veća u grupi dece rođene na vreme i iznosila je 92,5%, a u grupi prevremeno rođene dece 55,1%. Odgovori su izostajali obostrano kod većeg broja nedonešene dece u odnosu na decu rođenu na vreme, kod koje su izostajali jednostrano. Rezultati ponovnog pregleda pokazali su u grupi na vreme rođenih prolaznost 83,7%, a 61% u grupi nedonešenih. **Zaključak.** Prolazno izazvana otoakustička emisija je efikasan metod za ispitivanje sluha novorođenčadi, pošto je neinvazivna, brza i objektivna. Njena korelacija sa čujno izazvanim potencijalima je vrlo visoka, što potvrđuje njenu pouzdanost.

Ključne reči:
novorođenče; novorođenče, prevremeno; sluh; sluh, ispitivanje; evocirani potencijali, auditorni.

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Introduction

The importance of proper hearing function was reported even in 100 years before Christ by the Greek philosopher Epictetus, "Nature gave man two ears and one tongue so that he can hear twice more than he can say", what still counts nowadays, in time of communication necessity.

Hearing impairment can occur at any age, but the most severe one appear before or immediately after birth [1]. The consequences of these damages can cause speech and intellectual development function disorders. For these reasons, even from old times it was searched for an exact method for determining hearing function immediately after birth. Since hearing impairment is not just a personal problem, but of the whole society, nowadays centralized programs for systematic research (screening) of hearing impairment immediately after birth are conducted in order to detect and successfully treat impairment before the clinical symptoms appearance [2, 3].

Statistical data reveal that in 1,000 births, one to two newborns have hearing impairment, while in the group with risk factors, this number is higher and amounts to four [4]. Individual attempts of early detection of hearing function impairment were found in the distant past. In the 1980s, for example, a compulsory screening of neonates was introduced in the United States. It has become a mandatory diagnostic method, which demands detection of congenital hearing impairment within the first year of a child's life [5]. Since 1993, mostly in the countries of Western Europe, and recently in the neighboring countries, a universal newborn hearing-screening test has been applied. In our country, by an Act on National Program on Women, Children and Youth Health Care from April 24th 2009, a compulsory early neonatal hearing impairment screening test was introduced. Thus, the study included all newborns, those with positive test results to be controlled until hearing impairment found or excluded. Most commonly used methods are otoacoustic emission (OAE) and electrophysiological auditory brainstem response (ABR tests). Reliability of methods of OAE is estimated in the range of 80% to 98%, an automated ABR (AABR) from 84% to 90% [6].

In 1978, David Kemp first proved the presence of a feedback signal after cochlea stimulation by tones and pulses, calling them "evoked acoustic emissions". Otoacoustic emissions are low-pitched sounds that originate from physiologically clear cochlea. It is assumed that otoacoustic emissions are caused by the mobility of external cochlea cells that produce a wave by their frequencies movement, where a part of that energy returns through the oval window and inner ear and is detected in the corridor. Commonly used techniques, whose clinical reliability has been approved, are the evoked OAE, transient evoked OAE (TEOAE) and distortion product OAE – DPOAE [7]. They differ in the way they are generated and recorded but enable precise and frequency specific information. DPOAEs are generated by stimulating cochlea simultaneously by two clear sounds, which produces a third tone which differs form the two entering tones by frequency and can be separated and recorded. This method examines the frequency in the range of 1000 to 8000 Hz. In TEOAE a short-time click is used as a stimulus that activates the whole cochlea. By the DAE method, damage of the sensor-cochlea can be detected, but not its degree. If the cochlea function is normal, internally generated sound is recorded. However, in case of cochlear hearing impairment, cochlea either generates response that falls below the level that is expected for a normal hearing function or does not generate any response at all. If hearing impairment is greater than 30 dB at all frequencies, no answer is recorded. For testing, a soft probe is used, containing the microphone and micro speaker, which are placed in external auditory meatus. Automatic algorithms for response detection are implemented in the apparatus [8].

The aim of the study was to present the first results of systematic neonatal hearing function ability by a OAE method in the Clinical Center Kragujevac (Kragujevac, Serbia).

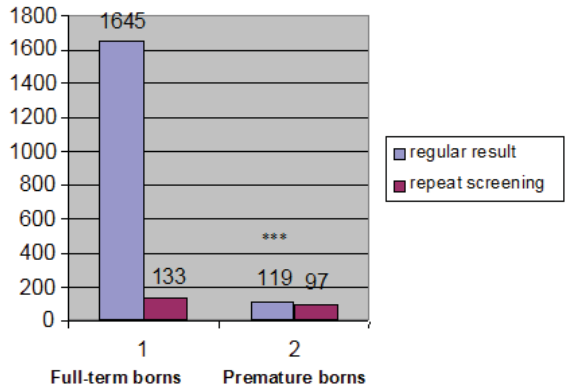
Methods

The program of systematic neonatal hearing function tests in the Clinical Center Kragujevac has been conducted since the late 2008. During this prospective study, from January 1st, 2009 until December 1st, 2010, 1,994 newborn infants were included out of who 1,778 were full-term and 216 premature born. The program was implemented according to a previously agreed protocol in collaboration with pediatricians-neonatologists. Full-term infants are examined in the Delivery Ward, within 24 h after birth – immediately after the delivery, during feeding and during sleep. Premature born children are examined in the Center for Premature Born Children when their general condition allowed that. Both ears are examined there by DPOAE Interacoustics OtoRead-screener, which is equipped with software algorithms for result recording and reading (Figure 1). Newborns with lateral or bilateral hearing impairment were scheduled for retesting in a month. The results of testing and retesting of full-term and premature born infants were then analyzed. Statistical method used was the χ^2 analysis by the Mantzel Haencel-test.

Fig. 1 – Performing neonatal screening for auditory function in the Clinical Center Kragujevac, Kragujevac, Serbia

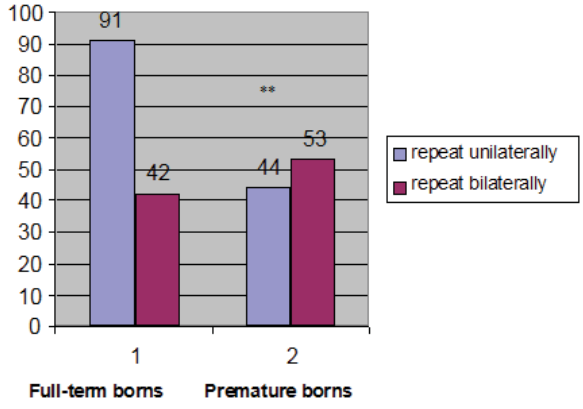
Results

Out of a total of 1,994 tested newborns, in 1,645 (92.5%) full-term infants and 119 (55.1%) premature born infants, the results were normal. Repeated examinations were required in 133 full-term born children and 97 prematurely born. The χ^2 analysis, done by the Mantzel Haencel test, showed that a significantly higher number of newborns in who repeated examinations were required was in the group of premature born children ($p < 0.001$) (Figure 2). The required repeated lateral and bilateral analysis frequency is presented in Figure 3. Conducted analysis showed that the necessity for bilateral reexamination was more frequent for the premature born children. Further testing and monitoring was necessary for 39% of preterm infants, while 83% of full-term newborns required no further monitoring (Figure 4), which is a statistically significant difference. Of the tested children, 2 full-term newborns, age 8 and 12 months, were diagnosed with a severe bilateral hearing impairment by other audiological test. They required hearing aids and auditory rehabilitation, too. One of them is a candidate for cochlear implant. Seven children required further audiological monitoring.



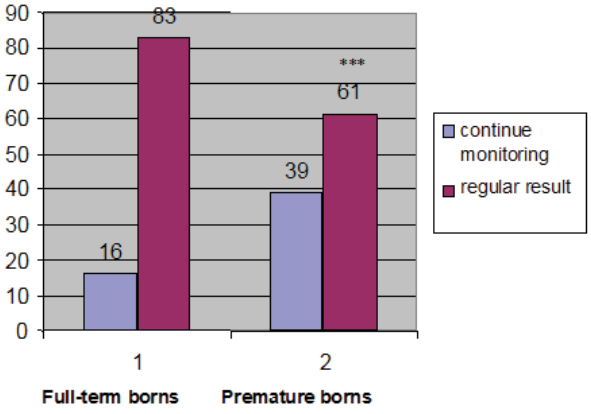
***$p < 0.001$ *vs* full-term borns children

Fig. 2 – Results of testing newborns by universal transient evoked otoacoustic emission (TEOAE) screening method



**$p < 0.01$ *vs* full-term born

Fig. 3 – The frequency of the need for unilateral or bilateral repeated screening



***$p < 0.001$ *vs* full-term born

Fig. 4 – The need for further monitoring of children following screening after a month from the first testing

Discussion

In our study, infants were at first divided in two groups – full-term delivered and premature born ones. Immediately after birth, prematurely born infants were moved to the Center for Premature Born Children, where further tests were done. In the premature born children, a number of those appeared to have positive test results on hearing impairment was recorded and the test was repeated for a large number of those infants. Out of a total number of tested infants, a higher test passing was reached in the full-term delivered children (92.5%), compared to 55.1% in preterm newborns, which represents a statistically significant difference. No response bilaterally was found in a number of premature born children compared to the full-term babies where responses were absent mostly unilaterally. After a month, retesting was done for all the children with the lack in responses, both bilaterally and unilaterally. Test passing in the group of full-term infants and in the group of preterm infants was 83.7%, and 61.2% respectively. Of the tested number, for the two full-term newborns a severe bilateral hearing impairment was detected, by other audiological tests, one at the age of 8 months and the second at the 12 months. Hearing aids were included and an auditory rehabilitation started. One of them was a candidate for cochlear implant. Seven children were scheduled for further audiological monitoring.

The results of screening by the otoacoustic emissions application in 904 newborns, at the Delivery Ward in the Clinics for Gynecology and Obstetrics at the Clinical Center "Zvezdara" in Belgrade, revealed passing on the first test in 86.3%, and in the second in 99.3% of newborns. In the two newborns unilateral hearing impairment was detected [9]. The study results of universal hearing sense screening in Sienna, Italy, in 19,000 newborns, tested by otoacoustic emission, showed that for 1.78 infant per 1,000 ones bilateral hearing impairment (35/19,700) was found. Hearing impairment di-

agnosis was set in the period up to 6 months [10]. Our research found bilateral hearing impairment in 1.05 newborn per 1,000 ones (2/1,994). The diagnosis was set in the period up to 12 months. In Australia since 2000, the universal hearing sense screening has being conducted, and so far, 25,000 newborns were tested in five main delivery wards in Perth. Results from 12,708 newborns report on screening passing of 99%, while 23/12,708 were scheduled for further auditory monitoring [11]. The screening program in newborns is considered as successful if the hearing sense unilaterally is checked for 95% of newborns. Neonatal screening of hearing function allows establishing the status of cochlea immediately after birth, because sensorineural hearing impairment in about 99% are related to abnormalities in its development [12]. The damage that is discovered and treated in the intensive establishment of synapses and the maturation of the neural auditory system from the 5th to 18th month (for children with hearing impairment hearing maturation time was extended to 4 years) has very good results, although consequences of congenital impairments can never be fully compensated [13]. Systematic testing of the hearing sense after birth required in newborn children, with special attention paid to children with prenatal or perinatal risk factors [14]. Our tests proved to be very significant. Systematic examination of hearing immediately after birth, was introduced as compulsory for all the newborn children in our town so that every newborn has to leave the maternity ward of the Center for Premature Born Children with a required importance is assigned to orderly hearing and that this is a real way to fight all the consequences of deafness. Mandatory neonatal screening of newborns for hearing impairment has not yet been implemented everywhere by our government, although there are now reliable methods available for its early detection as well as the protocol about its mandatory application. The reasons for this are inability to recognize the problem, ignorance, low health education and culture and health services oversights. Basically, this is done only in major medical centers, and when hearing impairment is suspected, a child is audiologically processed. It is easier to detect severe hearing impairment, while children with mild and moderate hearing impairments are often treated as children of lower intellectual ability or as mentally retarded children [15]. Application of universal neonatal hearing screening reduces the time of diagnosis setting and beginning of treatment in children with congenital hearing loss. Bibliography data indicate that prior to introduction of screening in the diagnosis, severe hearing impairment was diagnosed at the age of 12 to 13 months, medium hard impairment about the age of 17 months, while the introduction of screening reduced the age to 3 to 6 months [16]. The introduction of screening for hearing loss in newborns is also important from the economic aspect. The US National Center for Review, Evaluation and Management of Hearing Screening reports that detection and treatment of hearing impairment at birth for just one child saves about $ 400,000 in special education costs [17]. For introduction of neonatal screening for hearing impairment, as well as for its improvement, it is considered significant to improve data systems to support surveillance and monitoring, ensure that all children receive screening, capacity development of services, as well as to promote the importance of early detection [18].

Screening of hearing impairment program in newborns is considered successful if the hearing sense is tested unilaterally in 95% of newborns. The less number of false positive results and false negative ones for hearing impairment the better screening quality. Good screening includes less than 3% false positive results, and none with a negative false result [19]. It must be added that a certain number of children, mostly with risk factors, can develop a sensory hearing impairment, after birth and later, even after the good result on screening test. Results of screening of those neonates can be considered as false negative, however, it is important to recognize this risk category of children and retest them within the first 6 months [20]. By the screening method of otoacoustic emissions, it was impossible to detect retrocohlear hearing nerve impairment, CNS damages, functional hearing problems and central disorder of the speech message. Thus, additional research and professional monitoring is recommended for children whose risk factors (hypoxia, hydrocephalus, intracranial bleeding) can increase the possibility of this type of damage. This shows the complexity of this problem, which requires a comprehensive approach of the professional team of: audiologists, geneticians, neonatologists, defectologists, psychologists, preventive services, so that by application of a series of diagnostic, informative-educational, intervention and evaluative approaches early hearing impairments would be detected [21]. Causes of false positive results are mostly malformation and obstacles at the level of outer and medial ear, but those children must be treated with further diagnostic procedure up to a definite diagnosis. Despite the risk of false positive and false negative results, neonatal screening must be applied as compulsory in the whole country.

Conclusion

Neonatal screening for hearing function using otoacoustic emissions is a reliable and easy-to-perform test and this is exactly the right way to fight the effects of deafness.

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